tempted from these two locations, is successful, NASA estimates it can add anywhere from 3 to 5 months to Skylab's orbital life-span.

This would ensure that the third test shuttle would reach it—*if* the shuttle program is started on schedule. And according to William Taylor, the shuttle's budget director at NASA, "The probability of launching the first shuttle on schedule in March is very, very low." In fact, the agency is said to be running 4 months behind on the first launch. As of now, the agency is behind on its testing program for the shuttle engine, and faces the probability of even further delay as a result of a critique of the shuttle engine's safety currently under way at the National Academy of Sciences. Aller says that if the third shuttle cannot be launched on time, the Skylab mission could be moved forward even further, to the second test shuttle.

Total Loss More Than $1 Billion

Such a move raises questions about the cost and safety of performing the mission with a craft that will have been flown into space only once before. Aller admits that "we would have liked to have more experience with it [the shuttle] if it was feasible" prior to the Skylab mission. Taylor said that no estimate of the costs of moving the mission up has been prepared, but that total costs to the shuttle program "will be less than $1 million." Added to this will be the cost of speeding up development of the teleoperator retrieval system, although no estimate of this total has yet been made either. Moreover, if Skylab cannot be rescued in time, NASA will lose the satellite itself, plus the benefits of two studies on Skylab's reuse, plus the cost of the efforts to slow the satellite's descent. The total loss would come in at more than $1.1 billion. The teleoperator retrieval system itself will have lost its primary justification if Skylab comes down, although Aller claims that it would be a useful device on hundreds of missions in the next decade, with or without the Skylab mission. However, a staff member on the Senate subcommittee on Science and Space, which has been monitoring the recent Skylab predictions, noted that "without the Skylab mission, an entirely new case will have to made before we approve any funding of the teleoperator."

For this reason, NASA officials are understandably nervous about the entire issue of Skylab's plight. Although NASA has known since last November that Skylab was in trouble, it made no formal announcement about it until the middle of the Russian Cosmos incident. In all of their public statements, NASA officials have emphasized that Skylab contains no nuclear materials, and that 70 percent of its orbit is over water (70 percent of the earth is covered by water). They claim that the chance of Skylab causing any physical damage on earth is slim.

Against this background the facts remain that NASA went to a lot of trouble back in 1974 to be sure that Skylab would be around 10 years later, and that trouble was all for naught. In failing to boost it to a high enough orbit, the agency was a victim of circumstances. Once this had occurred, however, the agency delayed acknowledgment of and action on a warning by another federal agency that it was proceeding headlong into a troublesome situation. Attuned as it was to the political environment in which it operates, and probably the fact that this Administration has yet to formulate a formal space policy, NASA has all along done what it considered best. Now, it seems, all that it did was not the best at all.—R. JEFFREY SMITH

Government Seeking Ways to Encourage Aquaculture

Americans are not big fish-eaters, consuming 12 pounds per capita each year, which is peanuts compared with the 70 pounds per capita consumed in Japan. Nonetheless, this country imports more than half its fish, and the domestic haul has not increased since 1970. Thus we are now witnessing what may be a timely surge of federal interest in aquaculture.

Most people, if they think about aquaculture at all, have the vague notion that if we ever needed to cultivate fish and shellfish it would be easy to do so. Not so. As a report released this year by the National Academy of Sciences* indicates, most coastal areas are unavailable for aquaculture because of pollution or competing uses. Much research, particularly interdisciplinary work, needs to be done on the raising of fish in controlled environments. New enterprises are hazardous economically and are discouraged by a maze of government regulations. And no federal agency has been responsible for coordinating research or developing national policies for aquaculture.

There are some people who have been trying to do something about the situation for several years. The Commerce Department's National Oceanic and Atmospheric Administration (NOAA)—which puts more than $8 million a year into mariculture (marine aquaculture)—has had an interagency committee working for 2 years on devising a national policy. Last year the omnibus farm bill (the Food and Agricultural Act of 1977) for the first time explicitly mentioned aquaculture and designated the Department of Agriculture (USDA) as "lead agency" for research, extension, and education thereon. Finally, a number of bills have been introduced in Congress to encourage aquaculture, one of which passed the House on 15 February. That bill, introduced by Representative Robert L. Leggett (D–Calif.), chairman of the fisheries and wildlife subcommittee of the Committee on Merchant Marine and Fisheries, would make hundreds of millions of dollars available for loans and insurance to aquaculture businesses. It also designates Commerce as the lead agency, thereby setting the stage for a turf battle between the USDA and Commerce.

Aquaculture responsibilities are now divided among three cabinet agencies, the third being the Department of the Interior. Most aquaculture research is conducted under the auspices of Interior's Fish and Wildlife Service (fresh water) and NOAA (salt water). The FWS, which is oriented toward sport fishing, operates research stations, development centers, and hatcheries. NOAA puts about $10 million a year into aquaculture through its Sea Grant program and through the laboratories of the National Marine Fisheries Service. The USDA's involvement in aquaculture research has been minimal, and services in the field have mostly been limited to pond-digging and advice for catfish farmers.

**Aquaculture in the United States: Constraints and Opportunities* (Board on Agricultural and Renewable Resources, National Research Council, Washington, D.C., 1978).

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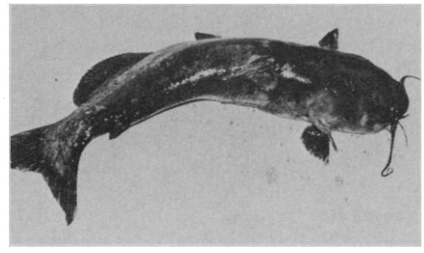
NOAA feels strongly that Commerce ought to be the lead aquaculture agency. It has been in the fish R & D business for 35 years, says David Wallace, former associate administrator for marine resources, who has been largely responsible for the agency's attempts to set up a coordinated national program. "Aquaculture is nothing to them [USDA]. It's big to us." But USDA, which wanted as little as possible to do with it under Nixonian Secretary Earl Butz, is now showing eagerness to exercise what it perceives to be its new mandate.

There are others who think that the question of who ends up carrying the ball is not as important as the need for a consistent federal policy and for measures to reduce the confusions and inhibitions that confront aquaculture at all levels of government.

It is difficult to grasp the status of aquaculture in America today. Some have compared it with that of chicken farming in the 1930's. An aquaculture plan published by NOAA last year says the situation is "roughly analogous to the state of agriculture before the Land Grant system and the Department of Agriculture launched intensive research programs to develop agricultural technology." That was 100 years ago.

Although some would like to portray it as a blossoming industry poised and waiting for the federal government to supply a few well-placed incentives to send it on a spurt of growth, the fact is that it is not an industry, but rather a fragmented collection of enterprises, most of them highly localized according to the characteristics of the species in question. Most operate at a fairly low level of technological and scientific sophistication. One might say at this point there is aquaculture and then there is aquaculture. There is a big difference between stocking rivers with fry from hatcheries and operating a total system where breeding is controlled, water quality and temperature are monitored, and the organisms are inoculated against disease and fed scientifically developed diets.

Take catfish farming. There are now about 1000 catfish farmers producing 48 million pounds a year—80 percent of it in three states: Mississippi, Arkansas, and Louisiana. Raising catfish is relatively simple as they are omnivorous and their life cycles are not as complicated as those of marine species. "The technology with catfish is just about as primitive as you can have and call it aquaculture," says Wayne Shell of Auburn University, one of the premier centers of aquaculture research. Catfish farming has grown rapidly in recent years, mainly because of improved disease control and the development of fish feed. The next generation of catfish culture may involve polyculture—that is, raising the fish together with carp or tilapias, which occupy slightly different ecological niches. Carp, which are bottom feeders, could filter out many waste products. This would reduce the effluent problem, make it possible to raise fish in greater densities, and make an additional species available for marketing. Also under consideration is the idea of raising catfish in silos, where water would be recirculated to make a closed system. This would have the advantages of saving water and making it possible to control temperature. However, it would require a lot of energy to keep the water aerated and purified, and if any part of the system broke down, the farmer could find himself with a crop of dead catfish in a matter of minutes.



Catfish

Growth Potential Varies

Because catfish are relatively easy and inexpensive to raise in warm climates, the catfish industry probably has more growth potential than that involving the other commercially viable freshwater fish—rainbow trout. Trout require huge quantities of fast-running, pure, cool water. They are raised in long shallow tanks called raceways. About 90 percent of the 30 million pounds of trout produced annually are raised in Idaho, where abundant fast-running water is supplied by the Snake River. Although trout farmers are working on persuading groups of trout to spawn at different times of the year so they can have uniform production (trout favor the colder months), widespread trout culture is inhibited by the limited availability of water and the energy costs of circulating and purifying it.

Salmon are a different story. At present 60 million pounds of salmon are produced a year from public hatcheries in Oregon, Washington, and Alaska, where they are caught in the public waters by commercial fishermen. There are budding efforts in the private sectors to raise salmon in two ways. One is called ocean ranching. Salmon are anadromous, which means that they spawn in fresh water and grow up in the ocean. Hatcheries release the young smolts and they swim out to sea. What makes a private salmon ranch possible is that salmon, through a chemosensing ability, always return to their birthplace to spawn. The vast majority of fish released never make it back from Japan, or wherever they go, but those that survive (maybe 1 or 2 percent) return to the hatchery.

The newer way of raising salmon is in pens, which is being done in Washington's Puget Sound. The pens are net enclosures where salmon are kept in high densities and given pelleted feed. This produces an entirely different product from ranched salmon because they are harvested after only 1 year, at which time they are "pan-sized," weighing about 1 pound.

These newer methods of raising salmon have yet to be proved economically viable for large-scale ventures. For ranching, site selection is a problem—for example, one wants minimal interference with returning adults. Disease control is still a problem for both ventures, and farmers are always looking for better conversion rates from feed, which is the most expensive part of the operation.

Oyster farming is another substantial aquaculture enterprise. Oysters have a complicated life cycle. After a few days the eggs become free-swimming larvae. In about ten more days the larvae attach to a substrate and grow shells, at which time they are called spat. When they have grown to about 1 inch they are seedlings. Hatcheries raise seed oysters and sell them to fishermen, who dump them in bays or other medium-salinity locations, where they attach to reefs of oyster shells.

But U.S. oyster production has been decreasing for many years since the peak of 152 million pounds in 1908. Disease, pollution, and siltation resulting from deforestation of watersheds have produced an apparently irreversible trend.

New ways to produce oysters are therefore urgently needed. The most advanced experiment in oyster culture is now being conducted by the University of Delaware at a laboratory on the Delaware Bay. The laboratory at Lewes is the nation's first experiment in using a totally controlled environment to raise oysters, which are fed on single-celled algae grown in tanks. Twelve adult oysters are kept on hand to do the parenting, and some rudimentary genetic information is obtained by keeping a record of the ancestry of every crop of eggs. Spawning can be closely controlled by putting males and females in separate

cups of water and raising the temperature to a provocative 82°F. Sperm and eggs are then mixed, with a resulting 80 or 90 percent fertilization rate. When larvae are ready to set, they are allowed to attach either to framed sheets of plastic or to a shallow tank paved with chicken scratch (crunched up oyster shells). The routine departs from traditional oyster-raising when the seedlings are separated from their substrate and placed in trays to grow up unattached and uncramped by their neighbors. The oysters are "force-fed" throughout their lives, says Kent Price, dean of marine studies. They are immersed in water with concentrations of algae that are 1000 times what they would get in the bay. The system is a closed cycle, with solid wastes and uneaten algae filtered out and used water recirculated to feed the algae with nutritious oyster waste products, namely ammonia and carbon dioxide. In this system, says Price, it takes 9 months to grow an oyster to marketable size, compared to several years in the bay. Price thinks the system could become commercially attractive within 3 to 5 years. Growing enough algae for the voracious population is a problem. "There are as many kinds of algae as terrestrial plants," says Price, who likes to compare the oyster operation with feedlot rearing of beef. "We're looking for the alfalfa, timothy wheat and sorghum of algae, not the cactus and greenbriers." Price believes that eventually polyculture will be possible, raising oysters with scavengers—say marine worms or shrimp—to tighten up the ecology.

Catfish, salmon, trout, and oysters are the only species extensively cultivated in this country. Crayfish farming is well established, but only in Louisiana, and 95 percent of the crop is consumed locally. Cultivation of marine shrimp shows promise but a major obstacle has to be overcome first—finding a way to get the animals to breed in captivity. Freshwater shrimp are being raised in Hawaii, but their spread elsewhere is constrained by the need for warm water. Work is being done with numerous other species of finfish and shellfish, but every one presents its own special problems. Lobsters, for example, are difficult to raise in captivity because they eat each other. All branches of aquaculture suffer to some degree from the fact that species under cultivation are essentially wild stock. However, the most serious inhibitors of the development of commercial aquaculture are not technical ones but, as the NRC report puts it, "political and administrative."

George Lockwood, a partner in Monterey Abalone Farms, is one businessman who has given a good deal of thought to the problems of commercial aquaculture. There are basically two sets of difficulties. One is the multiplicity of government regulations and regulatory bodies on all levels, which turn out to be particularly onerous for aquaculture because they were not set up with fish culture in mind. Lockwood says that he must deal with 42 different agencies, many of which have no provisions for aquaculture. For example, says Lockwood, "Our insurance carrier rates us a poultry farm."

Among other regulatory matters to contend with are the following.

- Environmental: the Environmental Protection Agency has not set up specific guidelines for fish rearing, and standards are left to the discretion of regional administrators. According to the NRC report, this is often a source of conflict with state water quality standards. Also, pollution abatement costs are often considered prohibitive by aquaculturists, some of whom have pleaded for special treatment in view of the small size of their operations.
- Food and drug laws: disease control is one of the major concerns of fish farmers. But many drugs that are permissible for use with, say, chickens have not been cleared for use with other species. Since it costs hundreds of thousands of dollars for pharmaceutical companies to test a new drug, testing for fish drugs proceeds at a slow pace as long as the market for them is small.
- Coastal zone planning: this is a particular problem in California. Within the next 2 years the whole coast will be tightly zoned. Aquaculture will have great difficulty in being exempted from restrictions on the siting of industry; in industrially zoned areas the water quality is too poor to support fish culture.

Even these constraints are not the major ones, says Lockwood. The growth of new enterprises is inhibited most by a series of changes in government fiscal policies over the past decade that have "distorted the flow of capital away from small, high-risk businesses." Tax laws, rules on pension fund investments, and changes in the securities industry are working to choke the small, experimental ventures and encourage investment in large, established, low-risk enterprises. And big corporations, which could afford to take the risks, are not doing so, in large part because of the web of regulations. A few companies—Weyerhauser, Inmont, and Union Carbide seem to be the main ones—have bought up profitable aquaculture operations in this country, but others are eyeing countries in Central America where there are more available coastal areas and fewer laws.

Aquaculture may be seen as a brand-new industry, really, that is struggling to assert itself through a web of economic and regulatory structures established before it came along.

It appears, then, that the situation confronting aquaculture is more diffuse and complex than the solution proposed by the Leggett bill would imply. As an agriculture committee staffer says, "Obviously there are problems beyond the fact of a little bit of high risk."

Some businessmen, like Lockwood, favor special insurance and loan programs as at least a first step in redressing an unfavorable economic situation. Others, namely catfish farmers, oppose such a step on the grounds that it would encourage inferior businessmen and fast-buck artists to get into aquaculture, default, cost the government a lot of money, and give aquaculture a bad name.

A more cautious approach to encouraging aquaculture is embodied in a bill introduced by Senator Richard B. Stone (D–Fla.). Like the Leggett measure, it calls for Commerce, Interior, and Agriculture to develop a national aquaculture plan and an interagency coordinating committee. Unlike the Leggett bill, it designates Agriculture as the lead agency. No amounts of money are mentioned in this measure. Rather, a comprehensive assessment is called for to determine the best course of action. The bill would also amend the federal crop insurance act to cover aquaculture, which up to now has been excluded.

It is too early to predict the outcome of congressional activity, but if the opinions of the NRC committee carry much weight, it is likely that something more along the lines of the Stone bill will prevail. The NRC report emphasized "equity" over special treatment, which would mean according aquaculture the same services (financial programs, extension, education) that are now available for agriculture. "Special treatment of any kind would be a detriment," says committee member Wayne Shell. "Aquaculture is capable of making its own way providing Agriculture accepts its responsibility." (The committee went along with the idea of making USDA the lead agency, even though its $100,000 study was paid for by the hopeful NOAA.)

Now that USDA has begun to show interest in aquaculture, assumption of leadership by that agency instead of NOAA made sense to most of the people contacted by *Science*. It has a huge research and field apparatus in place. And it is, after all, the food agency.

—CONSTANCE HOLDEN